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FORTRAN Program of Preparing Contour Maps for Geologic Use

by

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Abstract

A computer program was designed for preparing contour maps by the "Polyhedron Method". The program was written in FORTRAN for FACOM 230-60/75 by utilizing CALCOMP X-Y plotter Model 770/763. It can be easily modified for other computers which have more than 41 K words (or 164 K bites) of core memory.

The procedure of automatic contouring and the operating instructions of the program are described, and several test examples for geologic use are presented. The source list of the program is also carried in the appendix.

Introduction

A contour map is one of the most common ways of displaying geological quantitative areal data. Many mapping procedures (Bishop, 1960 for example) and their applications have been developed. They are isopachous maps (Merriam, 1955; Krumbein, 1962; Kanto Loam Research Group, 1965), isolith maps (Krumbein, 1962) and trend-surface maps (Krumbein, 1962; Merriam and Harbough, 1964; Schramm, 1968) in stratigraphy, and structure contour maps (Merriam, 1955; Kakimi *et al.*, 1973; Robinson and Charlesworth, 1969) and beta diagrams (Robinson, 1963; Noble and Eberly, 1964) in structural geology, for example. Besides, contour maps are generally used in display of many geophysical data, e.g. magnetic and gravitational ones.

However, it consumes time and cost to prepare contour maps by hand method. The quality of contour maps, when they are prepared by hand method, depends on an operator's technique and on his interpretation of data to be mapped. For the reasons mentioned above, most maps have been prepared only for data required specially to be displayed in contour maps, and they are nothing more than the illustrative maps. Consequently, not a few informations from collected data have been left to be used.

The computer has enabled to prepare standardized contour maps inexpensively and promptly, and the several procedures have been developed for computer contouring (Harbough and Merriam, 1968, p. 32; Cottafava and Mori, 1969;

KAWANO *et al.*, 1973).

There are two kinds of output media for contour maps which can be prepared by a computer; the one is a lineprinter and the other an X–Y plotter or drafter. A contour map made by a lineprinter is shown as a characters pattern in which the same characters are printed on the places where the values fall within the same ranges (YAMAMOTO, 1973). Therefore, it requires either raw or processed data regularly and densely spaced. Although it easily and promptly makes a contour map, it can not make any accurate one. It may be suitable for mapping functional surfaces. On the other hand, an X–Y plotter or a drafter has an advantage in that they can make much more precise and detailed ones. Besides, it can make a contour map directly even from irregularly spaced data.

The present program was designed for plotting a contour map by using an X–Y plotter in order to make the map from data irregularly spaced as well as from regularly spaced ones. It includes many options for geologic use.

The basic principle used in the program is the "Polyhedron method" discribed by HARBOUGH and MERRIAM (1968). The permission for using the principle is given from one of the authors (D. F. MERRIAM).

The program was made as one of the developping programs of Data Processing Center, Kyoto University (PROBLEM NO. 5001EY044 and 5001DY045). Any one who uses the program is required to have the permission from the present authors or Data Processing Center, Kyoto University.

Acknowledgement

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General Description of Program

This program produces a contour map from regularly or irregularly spaced data by using an X–Y plotter. The arrangement of a map on a plotting paper is shown in Fig. 1. This program is written in FACOM 230–60/75 FORTRAN (Fujitsu, 1970) which corresponds to IBM 360 FORTRAN IV (GERMAIN, 1967) using FACOM 230–60/75 SSL (Scientific Subroutine Library; FUJITSU, 1972) and CALCOMP routines (Yoshizawa Business Machines, 1969a and 1969b), and requires about

41K words (or 164 K bites) of core memory and 75 cm (29.5 inches) plotter. Many options are provided for geologic uses; input data selection, insertion of geographic data as a referring map and so forth (see b. Input options and c. Processing options).

a. Contouring procedure

By assuming that a surface to be mapped is represented as a polyhedron surface of triangular elements (named faces) each of which is defined by its peak points in a three dimensional space (Fig. 2), contour lines in a triangular element can be

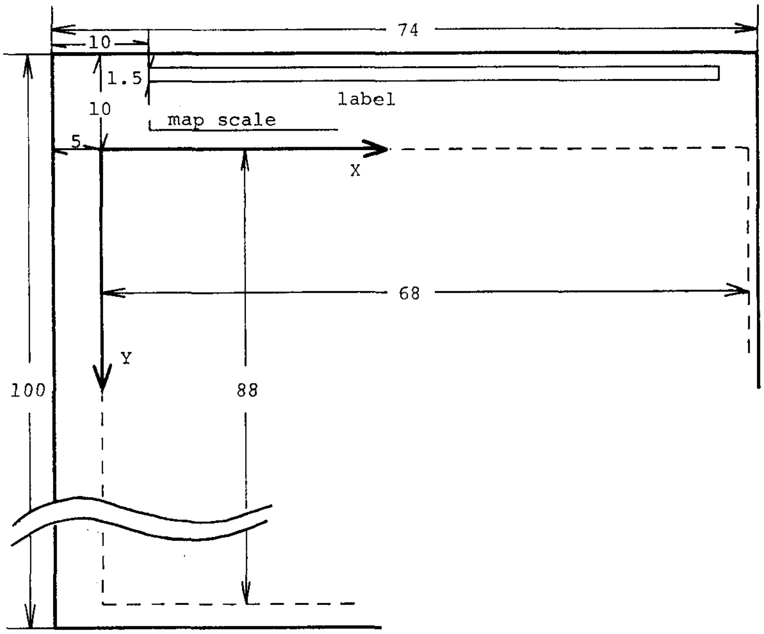


Fig. 1. Arrangement of output map on the plotting sheet. The contour map is drawn in the frame of broken line. The unit of length is expressed in cm.

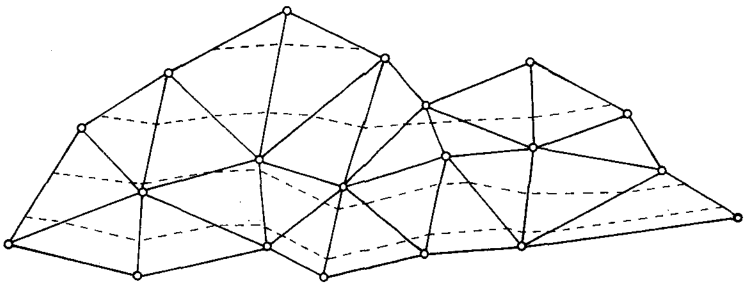


Fig. 2. Tetrahedron model illustrating the contouring procedure. The tetrahedron is constructed by triangular faces. Broken lines are contours.

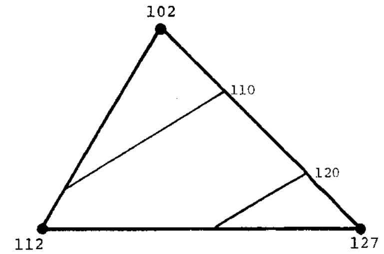


Fig. 3. Triangular face and interpolation for contouring. Slender lines are contours.

obtained by interpolation as shown in Fig. 3 (HARBOUGH and MERRIAM, 1968, p. 34). Conjunction of contour lines for all the elements yields a contour map of the surface to be mapped.

In this program, faces are automatically defined even if face definition is not directly given as input.

b. Input options

The following three kinds of data can be read as input:

(1) Irregularly spaced data with face definition

(2) Irregularly spaced data without face definition

A specified area to be mapped is derived into rectangular grid units, and the units are sequentially numbered. The value at a given grid point (named the grid value) is computed by approximation of the observations in the specified

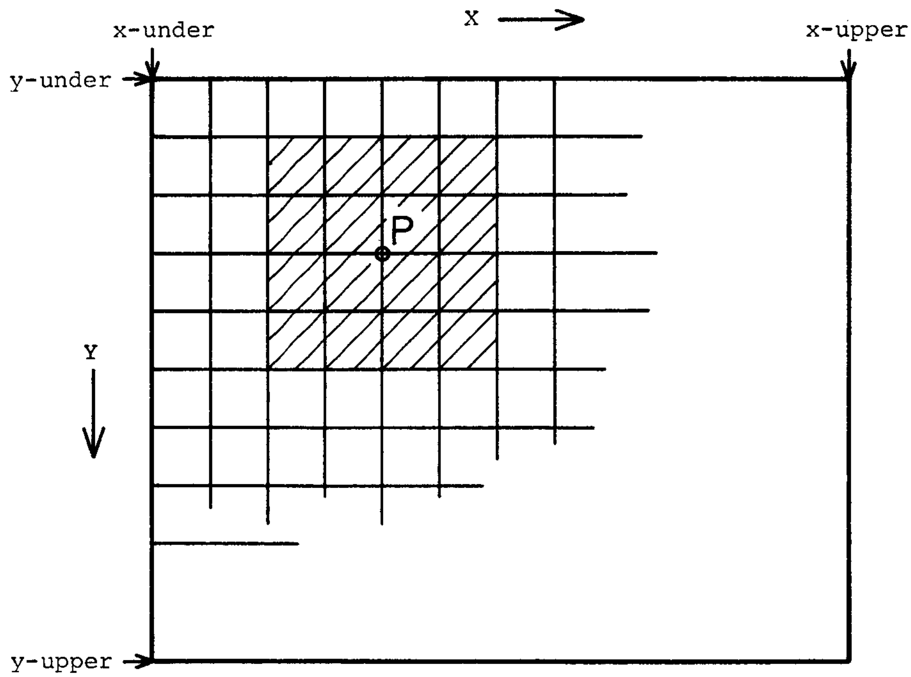


Fig. 4. Mapping area, grids, and grid units. Observations in hatched area are used to estimate the grid value at point P. The area should be specified as input using the number of units. In this case, the number is 2.

number of units around the grid point (Fig. 4). As a result, regularly spaced data are completed (see to HARBOUGH and MERRIAM, 1968, p. 35). (The more number of units are specified as the area in which observations are, the map will be more smoothed.) Then each unit is subdivided into two triangular elements (faces), and the elements are automatically defined by using grid point numbers given before.

(3) Regularly spaced data

This kind of data should be grid data regularly spaced as mentioned above. The units formed by grids are subdivided into triangular elements, and they are automatically defined as in (2).

c. Processing options

The following three kinds of processings can be optionally performed:

(1) Insertion of referring point(s), line(s) and/or map scale.
(2) Plotting of data points with their numbers and values.
(3) Specification of blank unit(s), i.e., rectangular one(s), in which no contours are to be drawn; valid in the input cases of b–(2) and b–(3).

d. Input medium

Cards and an alternative tape can be used an input medium for source data input.

e. Limitations

(1) # of peaks, NOP$\leq$1000.
(2) # of faces, NOF$\leq$2000.
(3) # of rectangular units, NNN$\leq$1000.
(4) # of referring points, NUMBER$\leq$100.
(5) # of referring lines, NLINE$\leq$10.
(6) # of control points on a referring line, 3$\leq$NPFOLN$\leq$100
(7) Others: refer to Input Instructions.
(8) Map size: width (x–direction) and length (y–direction) are less than 68 cm and 88 cm respectively in the case of using Data Processing center, Kyoto University (refer to Fig. 1 for the map arrangement and to Fig. 7 for the coordinate system).

f. Output

(1) List of processing specifications
(2) Input
(3) Tracing informations of processing
(4) Error messages
(5) Contour map

g. Error treatment

Error checks are carried out on the following items, and error meassages are printed out, if any errors are detected:

(1) Kind of input data:

If any code other than FDEF, SMTH, REGS are detected, the processing will be stopped with a message "ILLEGAL DATA KIND" (refer to Input Instructions-B-c).

(2) Computed results of grid values:

If a grid value is not normally obtained, a message "GAUELS ERROR, APPROXIMATING PLANE WAS NOT DETERMINED" will be printed out, and any contours will not be drawn in all the units concerned with the grid point.

(3) Specification of blank unit(s):

If any illegal specification is detected, the processing is stopped with a message "BLANK AREAS DEFINITION ERROR" (refer to Input Instructions-B-(g.)).

(4) Repetition times number of main repeating operations:

Amount checks are carried out on the items in Tab. 1. If an amount exceeds its limitation, it will be printed ont in the form "**ERROR** CONTROL VALUE IS ILLEGAL........." and the processrng will be stopped.

(5) # of contour lines:

If contour lines are to be too densely drawn in a triangular element, the lines which exceeds the limitation (100 lines) will not be drawn, and a message "LINES TO BE DRAWN OVER 100" will be printed out.

Processing Procedure

The processing is performed according to the following flow of steps (Fig. 5, Process flow chart).

Step 1. Data and task specifications are read as input from cards.

The program control proceeds to step 2, 3, or 4 according to the kind of source data; to Step 2, when they consist of peak and face definition data, to Step 3, when only peak ones, and to Step 4, when regularly

Tab. 1. Check list of main iteration mumbers.

#	Code	Limitation	Test Matter
1	MAP#	10	# of sets of regularly spaced data in a tape
2	MAXX	200	# of grids in x-direction
3	MAXY	200	# of grids in y-direction
4	NOP	1000	# of peaks
5	NOF	2000	# of faces
11	RPO#	100	# of referring points
12	PLN#	10	# of referring lines
13	RLP#	100	# of control points on a referring line
14	MARK	200	# of marks on a map scale

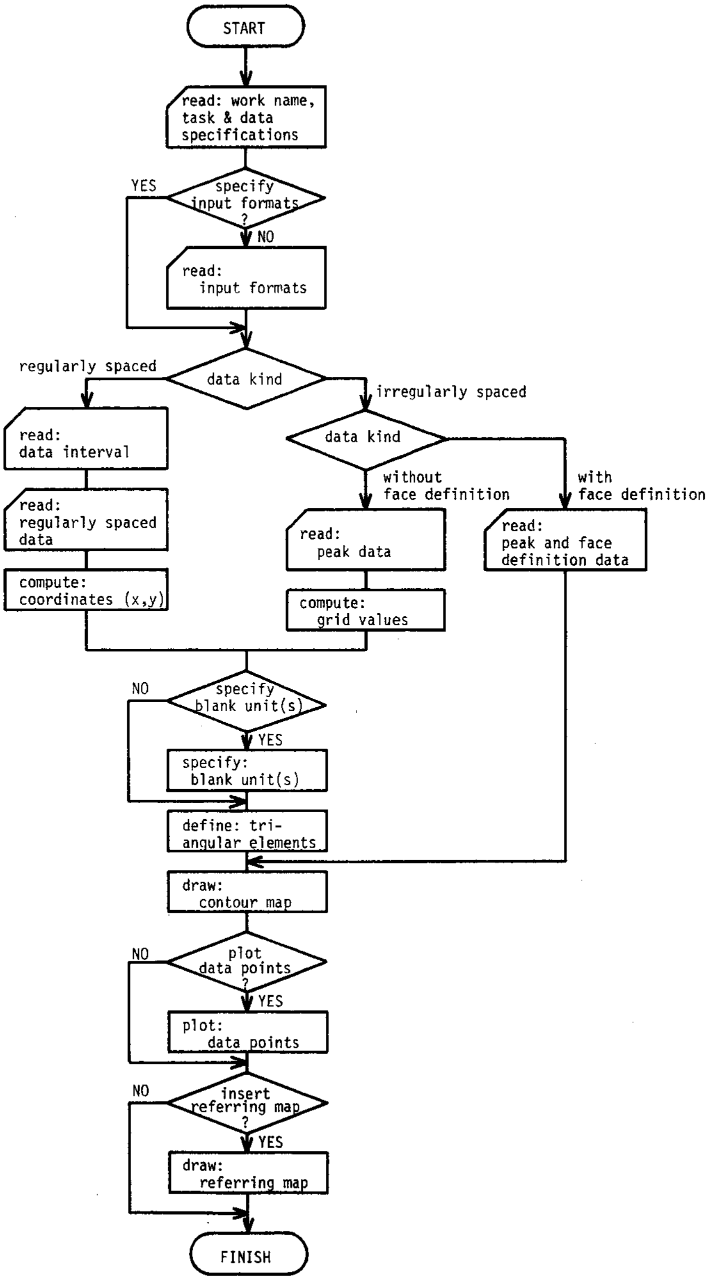


Fig. 5. Process flow-chart of program.

spaced ones.

Step 2. After input of peak and face data, it proceeds to Step 7.

Step 3. Peak data are read as input. After completion of grid values, it proceeds Step 5.

Step 4. Regularly spaced data are read as input.

Step 5. Triangle definition is performed.

Step 6. (Optional) Blank unit(s) is/are defined according to input from card(s), if required.

Step 7. Contour lines are drawn.

Step 8. (Optional) Data points and their numbers and values are plotted, if required.

Step 9. (Optional) A referring map is drawn, if required.

Input Instructions

A. Order of cards in deck

An example is shown in Fig. 6 in FACOM 230–60/75 cases. Cards indicated by items of letter enclosed in parentheses are optional.

a. System cards*
b. Problem/data name card
c. Task and data specification card–a
(d.) Input format cards
e. Task and data specifiction card–b
f. Data input cards if data are recorded on cards.
(g.) Blank unit(s) specification card(s)
(h.) Referring map data input cards
i. System cards*

```
 $NO
 $KJOB
  COND=500
 $FORTLINK
 program deck
 $PLOTRUN MAX=100
 data deck
[$FD F08,FILE=(OLD,CKA367.XXX),UNIT=DP0,VOL=(SPEC,PF5014)]
      If all input data are to be read from cards,
      this system card is not required.  The underlined
      are the file name and volume name.
 $POUT
 $JEND
```

Fig. 6. Setup example of card deck. The statements with marks "$" indicate system cards. The one in the bracket is necessary to define an input file which is alternative to input data cards.

* These cards are required to control a job. The forms depend on the convention of each computer center. Consult to your computer center.

B. Card preparation

b. Problem/data name card

Col. 1–80 Alphanumeric problem/data name; characters only in 1–40 columns are plotted on the output map.

c. Task and data specification card–a

Col. 1–4 FDEF: if face definition data are to be read as input.
SMTH: if only peak data are to be read as input.
REGS: if regularly sapced data are to be read as input.

10 Input device logical # for peak or regularly spaced data (1 to 4 and 8 avairable); if not specified, 5 (card reader) is used as a default value.

15 Input device logical # for face definiton data (1 to 4 and 8 avairable; must be not the same as that for peak data); default is 5 for a card reader.

16–18 YES: if a referring map is to be plotted; otherwise leave blank.

21–30 YES: if blank unit(s) specification is/are to be performed; otherwise leave blank.

26–28 YES: if peak points are to be plotted; otherwise leave blank.

31–35 Skip # for plotting peak points; when 1, all points will be plotted.

36–40 # of digits of the decimal part to be plotted as peak values. If it is punched in a negative number, peak values are not plotted.

41–50 Base value of contours; real with a decimal point.

61–70 Scaling factor for plotting; if it is left blank, the map is automatically scaled.

71–75 0: if only a map scale is to be plotted.
1: if only referring point(s) is/are to be plotted.
2: if only referring line(s) is/are to be plotted.
3: if referring point(s) and line(s) are to be plotted.

Note: if the map scale is also to be plotted in the case of 1, 2, 3, negative number should be punched, i. e. –1, –2,–3.

76–78 YES: if input format(s) is/are to be specified; otherwise leave blank.

(d.) Input format cards (Optional)

If input format(s) for peak and/or face definition data is/are to be specified, both of two format cards for peak and face definition should be prepared. If input of face definition data is unnecessary, leave the second card blank.

Card 1. For peak data input:

(1) If regularly spaced data are to be read as input, this specifies the format of values (z) at regularly spaced points (i. e. at grid points). If not specified, the format (8(6X, E10.4)) is used as a default one.

(2) If irregularly spaced data are to be read as input, this specifies the format of a peak #, its location (x,y) and value (z) (see Fig. 7 for the coordinate system). The default is (2(I5,3F10.0, 5X)) for two peaks in a card.

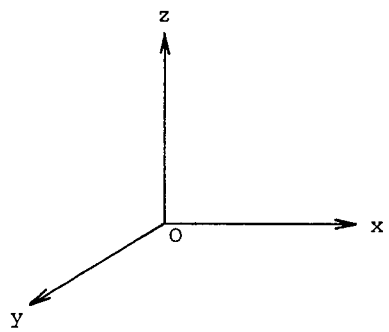


Fig. 7. Coordinate system. All the input data should be measured according to the system.

Card 2. For face definition data input:

If face definition data are to be read as input, this card should be punched; otherwise leave blank. In the case of to be read, this specifies the format for arbitrary # of face definitions, each of which consists of three peak numbers to define a triangle. The default is (4(3I5, 5X)) for four faces in a card.

e, f. Task and data specification card–b, and data input cards.

All data input cards should be punched according to the formats specified on the input format cards or to the default formats. If source data are to be read from an alternative tape, they should be also written to the formats. In the case of using an alternative tape, task and data specification card–b should be prepared.

The following three types of data (see General Description of Program) can be chosen as the source data:

(1) Peak and face definition data (The task and data specification card–b is Card 1).

Card 1.	Col.	1– 5	# of peaks
		6–10	# of faces
Card 2.			Peak data: peak #, coordinate of location (x,y).
Card 3.			Face definition data; see the explanation of (d) Card 2.

(2) Peak data without face definition (The task and data specification card–b is Card 1).

Card 1.	Col.	1– 5	# of peaks
		6–10	# of units for the computation of grid values (see General Description of Program); if autoextension is necessary, punch in a positive number, and if not, in a negative one.
		11–20 21–30 31–40 41–50	Boundaries of the mapping area in the original coordinate system; x-under, upper, and y-under, upper respectively; real with a decimal point (see Fig. 4).
		51–60 61–70	Side lengths of a unit in the original scale; x and y directional ones, respectively (see Fig. 4)

(3) Regularly spaced data

If the data are to be read from an alternative tape, see **Note.**

Card 1.	Col.	1–10	Pitch of data points in x-direction
		11–20	Pitch of data points in y-direction
		21–25	# of data points in x-direction
		26–30	# of data points in y-direction
Card 2.			Values (z): punched according to the specified or default format.

Note: If the source data are to be read from an alternative tape, an ID-card in which ID-code and # are written in the format (A4, I5) is required instead of Card 1 described above. A data set whose ID-code and # coincide with the ones of ID-card is read as input. The data in the tape should be written in the following forms:

Section 1. File code and # of data sets in the file should be written in the format (A4, I5).

Section 2. ID-code, # and pitch and #s of data points in x, y-directions are written in the format (A4, I5, 2F10.0, 2I5).

Section 3. Values (z): in the specified or default format.

Sections 2 and 3 make a data set. As many sets as # of data sets written in Section 1 should be stored in the tape.

(q.) Blank unit(s) specification card(s)

16 sets of data can be punched on a card at most. Each set of data consists of unit # (4 columns) and a delimiter (1 column); blank, comma, hyphen, or slash. If a blank or comma is punched as a delimiter, only the unit which corresponds to the # in the set is defined as a blank unit. If a hyphen is punched as a delimiter, all the units from the one of the #s punched in the set to the one of the #s punched in the next set. But this type of specification should be kept in the same card. The delimiter of slash indicates the end of the specification. An example is shown in Fig. 7.

(h.) Referring map data input cards

(1) Referring point(s) input cards

Card 1. Col. 1– 5 # of referring point(s)

Card 2. Prepare one card for a referring point.

Col.	1–10	x-coordinates of a referring point; real with a decimal point
	11–20	y-coordinates of a referring point; with a decimal point
	21–30	Size of a referring point (cm); real with a decimal point
	31–40	Size of referring point name (cm); real with a decimal point
	41–60	Name of a referring point
	61–70	Symbol code (numeric) of a referring point

(2) Referring line(s) input card

Card 1. Col. 1– 5 # of referring lines

Card 2.

Col.	1– 5	# of control points on a line
	6–15	Size of line name (cm); real with a decimal point
	16–25	Inclination of the name (degrees anti-clockwise) from y-direction; real with a decimal point
	26–45	Line name

Card 3. Prepare as many as desired for a line. Four sets of coordinates (x,y), i.e. eight values, can be punched on a card at most; real with a decimal point.

Note: A set of a Card 2 and Card 3 as many as desired should be prepared for a line. Prepare those sets as many as the # of referring lines specified in Card 1.

(3) Map scale input card

Col. 1–10 Length of the map scale (cm): actual length on the marks output map; real with a decimal point (see Fig. 8)

11–15 # of marks in the map scale: include both of side (see Fig. 8).

16–23 Actual distance of the map scale (alphanumeric): plotted on the right shoulder of the map scale (see Fig. 9).

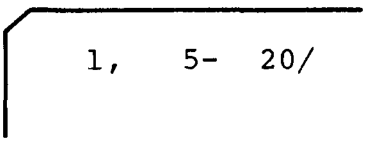


Fig. 8. Example of blank unit specification data. This example specifies the units #1 and #5 to #20 to be blank units.

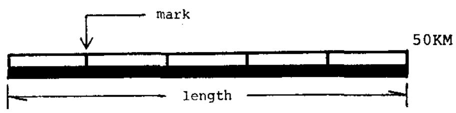


Fig. 9. Map scale to be plotted in the output map.

Processing Examples

A. Test examples

(1) Irregularly spaced data

The data are concerned with the water depth of the Pacific off Hachinohe, Northeastern Japan, and derived from Hydrographic Department, Maritime Safety Agency, Japan. Two kinds of contour maps were prepared; the one from both peak and face data, and the other only from peak data. The input and the output maps for the former are shown in Fig. 10, those for the latter in Fig. 11. The contour lines in Fig. 11 are more smoothed than those in Fig. 10. The contour values can be obtained from the peak values in the former case and from the grid values printed in the output list in the latter case.

(2) Regularly spaced data

Two kinds of processing were performed on the regularly spaced data; the one with and the other without the blank units specification. The input and the output maps are shown in Figs. 12 and 13. The contour values can be obtained from the grid values in the input.

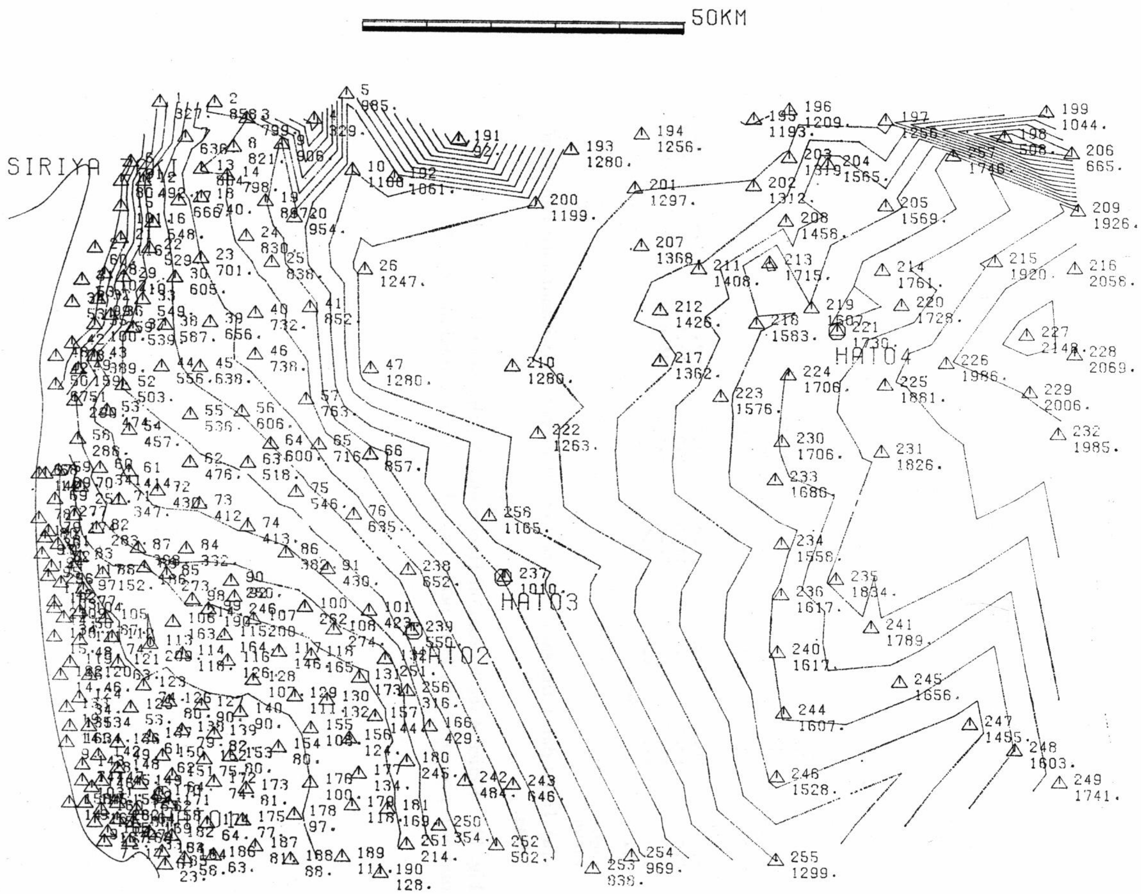
B. Application.

Isopacous map of the Imaichi Pumice Bed. Fig. 14a is by this program and Fig. 14b is in "The Kanto Loam". The pumice bed was supplied from the mountain of Nantaisan, which is one of the Quarternary volcanos in the Kanto district, Japan. Data from Kanto Loam Research Group (1965).

```
$KJOB      50010W036,YAMAMOTO.KAI,500331,
 CORE=60K,LP=6000
$DPFORT FILE=CKA367.CMPP,VOL=PF5005
$PLINKRUN MAX=100
RELIEF OF SEA BOTTOM, NO. 1 (HACHINOHE)
EDEF            YES       YES                       100.      0.5         -3
  258  448
  001 4.7       1.7       327.0             002 6.4       1.7       858.0
  003 7.4       2.2       799.0             004 9.5       2.2       329.0
  005 10.5      1.4       985.0             006 3.8       3.6       91.0
                                      .
                                      .
                                      .
                                      .
  255 24.0      25.3      1299.0            256 12.5      20.1      316.0
  257 29.4      3.2       1746.0            258 15.0      14.6      1165.0
  001  002  007       002  003  007         003  008  007       003  009  008
  003  004  009       004  005  010         004  010  020       004  020  009
  009  020  019       009  019  014         009  014  008       008  014  013
                                      .
                                      .
                                      .
                                      .
  233  230  231       258  233  234         258  222  233       179  189  178
  200  201  207       201  202  207         224  221  225       223  230  233
   5
0.         3.5                0.5       SIRIYA ZAKI            64
12.7       18.2      0.5      0.5       HAT02                   1
4.9        23.4      0.5      0.5       HAT01                   1
15.45      16.5      0.5      0.5       HAT03                   1
25.8       8.7       0.5      0.5       HAT04                   1
   1
  14
0.0         5.4       0.9       5.0       2.3       3.7       1.4       8.0
1.0        10.0      1.1       11.1      0.9       13.6      1.0       16.8
1.3        19.7      1.9       22.6      2.8       25.0      3.7       25.5
4.2        25.2      4.8       26.0
10.             650KM

$POUT
$JEND
```

(a) Input data: title card, control cards, peak data (two sets in a card each of which consists of peak #, coordinates and depth of the point), face definition data (four sets in a card each of which consists of three peak point #s), and data for referring points, line and a map scale.

Fig. 10. Relief of sea bottom off Hachinohe, Northwestern Pacific. This contour map was prepared from peak and face definition data derived from Hydrographic Department, Maritime Safety Agency, Japan.

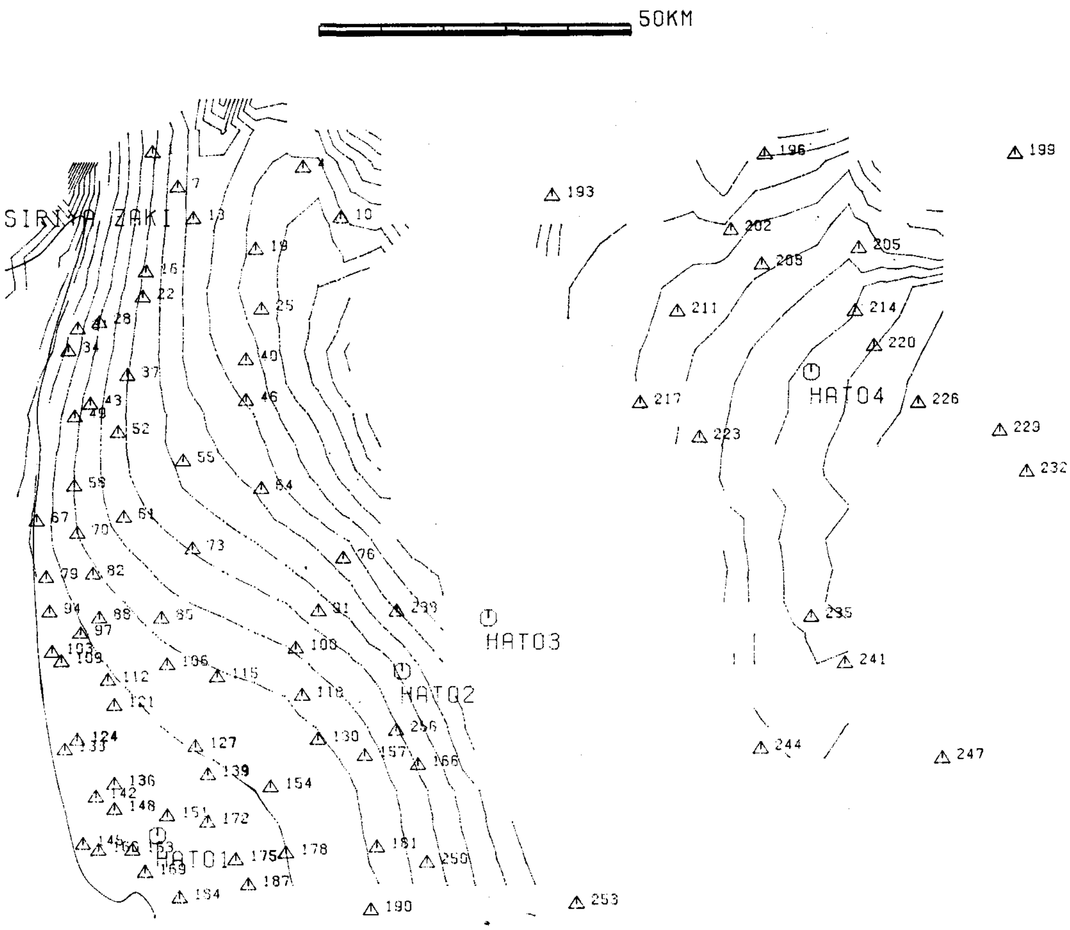


(b) Output map: shorline, and data points with their #s and values (depth) are plotted; contour values can be obtained from peak values.
Fig. 10 (continued)

```
$KJOB      50010W036,YAMAMOTO.KAI,500331,
 CORE=60K,LP=6000
$DPFORT FILE=CKA367.CMPP,VOL=PF5005
$PLINKRUN MAX=100
RELIEF OF SEA BOTTOM, NO. 1 (HACHINOHE)
SMTH            YES          YES        3   -1          100.0      0.5          -3
  258    -3             30.                   25.          1.         1.
  001 4.7      1.7         327.0                 002 6.4       1.7          858.0
  003 7.4      2.2         799.0                 004 9.5       2.2          329.0
  005 10.5     1.4         985.0                 006 3.8       3.6          91.0
                                       .
                                       .
                                       .
                                       .
  255 24.0     25.3        1299.0                256 12.5      20.1         316.0
  257 29.4     3.2         1746.0                258 15.0      14.6         1165.0
   5
0.         3.5                   0.5        SIRIYA ZAKI           64
12.7       18.2       0.5        0.5.       HAT02                  1
4.9        23.4       0.5        0.5        HAT01                  1
15.45      16.5       0.5        0.5        HAT03                  1
25.8       8.7        0.5        0.5        HAT04                  1
   1
  14
0.0         5.4        0.9        5.0        2.3        3.7        1.4        8.0
1.0        10.0        1.1       11.1        0.9       13.6        1.0       16.8
1.3        19.7        1.9       22.6        2.8       25.0        3.7       25.5
4.2        25.2        4.8       26.0
10.           650KM

$POUT
$JEND
```

(a) Input data: the same that of Fig. 10 except for without face definition data.

Fig. 11. Relief of sea bottom off Hachinohe, Northwestern Pacific. This contour map was prepared only from peak data which are also used in Fig. 10.

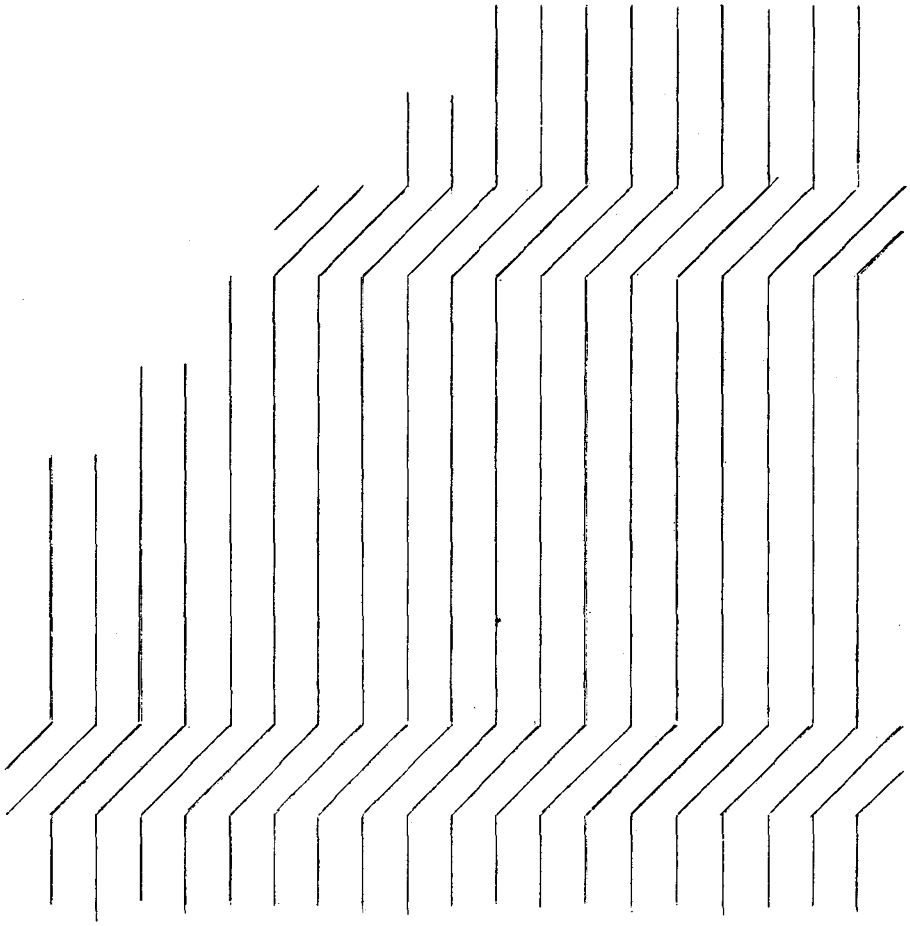


(b) Output map: the grid data each of which was estimated using the peak data around the grid point by least squares method; blank areas are due to scarcity of the peak data around the grid points; shoreline and data point with their #s are plotted; contour values can be obtained from the grid values in the output list.

Fig. 11. (continued)

```
$KJOB     50010W036,YAMAMOTO.KAI,500331,
 CORF=60K
$DPFORT NOLIST,NOMAP,FILE=CKA367.CMPP,VOL=PF5005
$PLINKRUN MAX=100
TEST FOR REGULARLY SPACED DATA
REGS                 YES                                  0.5                  1.0     YES
(80F1.0)

2.          2.            11   11
0123456789801234567898012345678981234567898712345678987123456789871234567898712З
456789871234567898723456789876234567898762345678987б
   1-   5,  11-  14,  21-  23,  31,  32,  41/
$POUT
$JEND
```

(a) Input data: title card, control cards, grid data, and blank unit definition data.

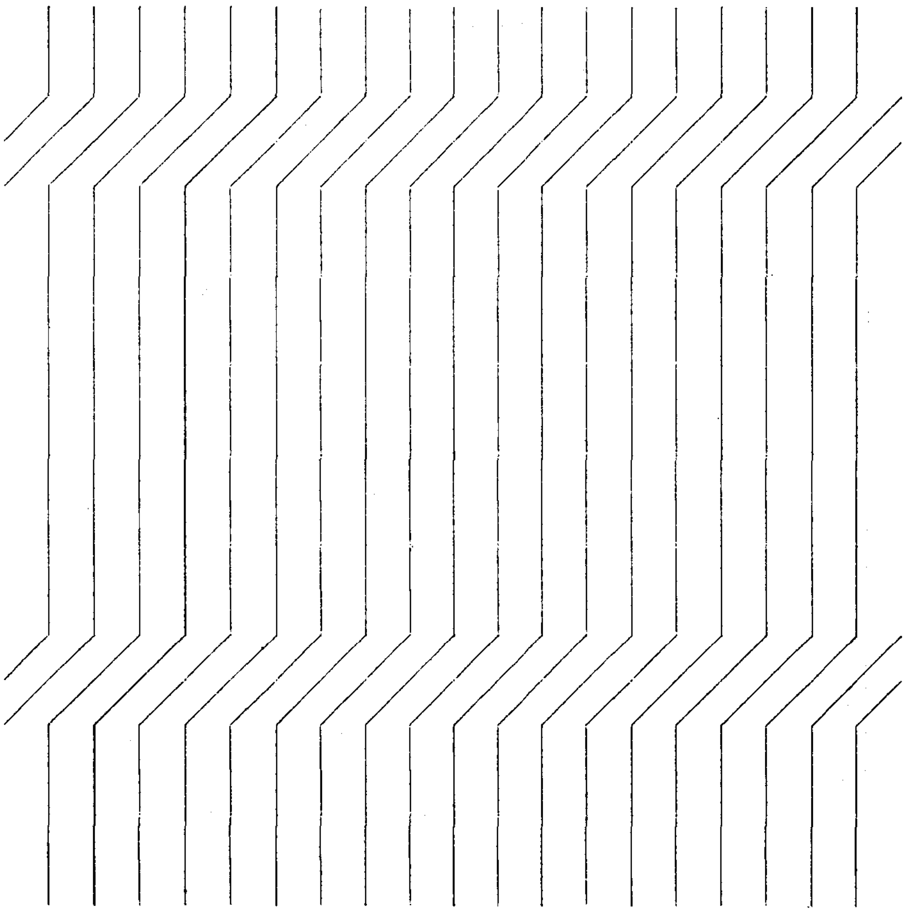


(b) Output map: blank areas are due to the blank unit definitions; contour values can be obtained from the grid values in the input.

Fig. 12. Processing example of regularly spaced data with blank unit definitions. The data are arbitrarily prepared for the test processing.

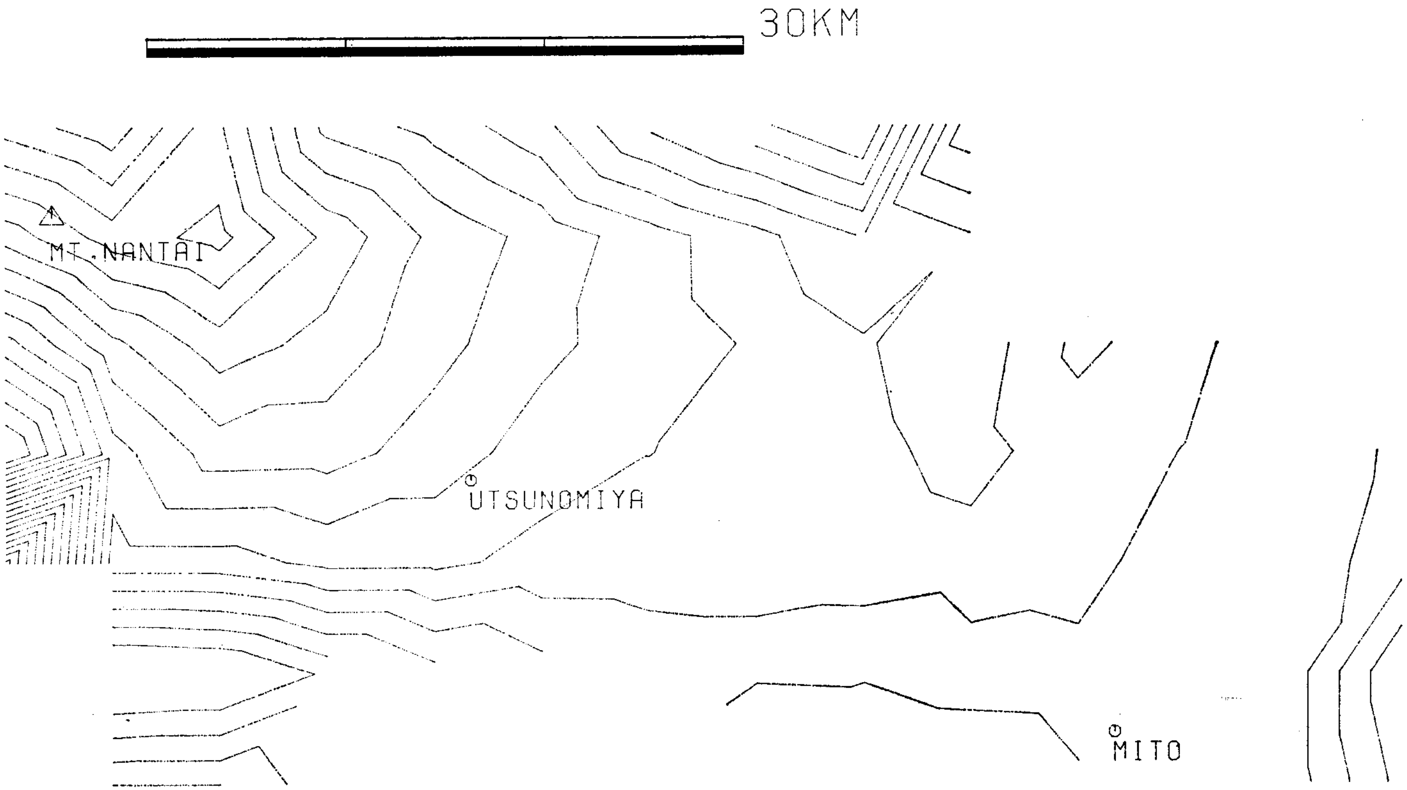
```
$KJOB      50010W036.YAMAMOTO.KAI.500331,
 CORE=60K
$DPFORT NOLIST,NOMAP,FILE=CKA367.CMPP,VOL=PF5005
$PLINKRUN MAX=100
TEST FOR REGULARLY SPACED DATA
REGS                                         0.5                 1.0      YES
(80F1.0)

2.         2.          11   11
0123456789801234567898012345678981234567898712345678987123456789871234567898712 3
456789871234567898723456789876234567898762345678987 6
$POUT
$JEND
```

(a) Input data: the same that of Fig. 12 except for without the blank unit definition data.



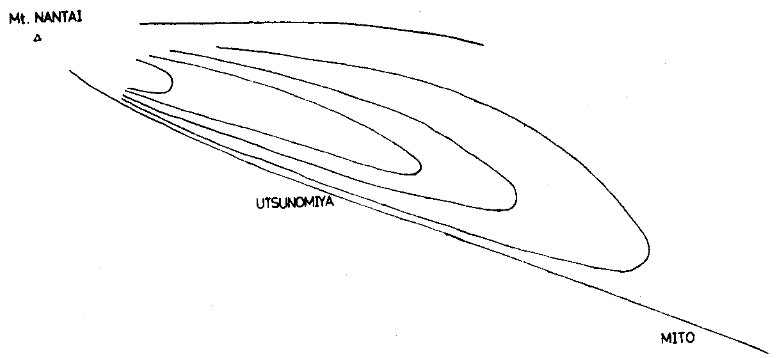
(b) Output map.

Fig. 13. Processing example of regularly spaced data without blank unit definitions.



(a) Smoothed contour map drawn by the program: peak data, data for referring points and a map scale are used, all of which are from Kanto Loam Research Group (1965).

Fig. 14. Isopacous map of the Imaichi Pamice Bed (Late Quarternary), the Kanto district, Japan.



(b) The one compiled by Kanto Loam Research Group: from Kanto Loam Research Group (1965).

Fig. 14. (continued) Both of the maps show the distinct trend that the thicker the bed the nearer to the moutain of Nantai-san. The latter is more generalized, while more detail changes are expressed in the former.

References

BISHOP, M. S. (1960), *Subsurface mapping*, John Wiley & Sons, Inc., New York, London, 198 pp.

COTTAFAVA, G., and MOLI, G. L. (1969), Automatic Contour Map: *Communications of the ACM*, **12**(7), pp. 386–391.

Data Processing Center, Kyoto University (1973), *Manual for using X-Y plotter*, File no. K-UG-0013-1. (in Japanese)

FUJITSU (1972), *FACOM 230-60 SSL (Scientific Subroutine Library) Manual for FORTRAN*, File no. 230/60-301 309-001-7. (in Japanese)

——— (1970), *FACOM 230-60 FORTRAN*, File no. SP-061-4-4. (in Japanese)

HARBOUGH, J. W., and MERRIAM, D. F. (1968), *Computer Applications in Stratigraphical Analysis*: John Wily & Sons, Inc., New York, London, and Sydney, 282pp.

KAKIMI, T., KINUGASA, Y., and KIMURA, M. (1973), 1/500,000 Neotectonic Map Tokyo: *Tectonic Maps series 2*, Geol. Surv. Japan, Kawasaki, Japan.

Kanto Loam Research Group (1965), *The Kanto Loam–its origin and nature*, Tsukiji Shokan (or Pub. Co.), Tokyo, Japan, 378 pp.

KAWANO, K. *et al.* (1973), An Approach of Contour Mapping: *Jour. Inform. Process. Soc. Japan*, **14**(12), pp. 916–924. (in Japanese with English abstract)

KRUMBEIN, W. C. (1962), Open and closed number system in stratigraphic mapping: *Am. Assoc. Petroleum Geologist Bull.*, **46**(12), pp. 2229–2245.

MERRIAM, D. F. (1955), Jurrassic rocks in Knasas: *Am. Assoc. Petroleum Geologist Bull.*, **39**(1), pp. 31–46.

———, D. F., and HARBOUGH, J. W., (1964), Trend-surface analysis of regional and residual components of geologic structure in Kansas: *Kansas Geol. Survey Sp. Dist. Publ.*, **11**, 27 pp.

NOBLE, D. C., and EBERLY, S. W. (1964), Discussion: A digital computer procedure for preparing beta diagrams: *Am. Jour. Sci.*, **262**(9), pp. 1124–1129.

ROBINSON, J. E., and CHARLESWORTH, H. A. K. (1969), Spatial filtering illustrates relationship between tectonic structure and oil occurrence in southern and central Alberta: *Kansas Geol. Survey Computer* Contr. **40**, pp. 13–18.

ROBINSON, P. (1963), Preparation of beta diagrams in structural geology by a digital computer: *Am. Jour. Sci.*, **261** (10), pp. 913–928.

SCHRAMM, M. W., Jr. (1968), Application of trend analysis to Pre-Morrow surface, southeastern

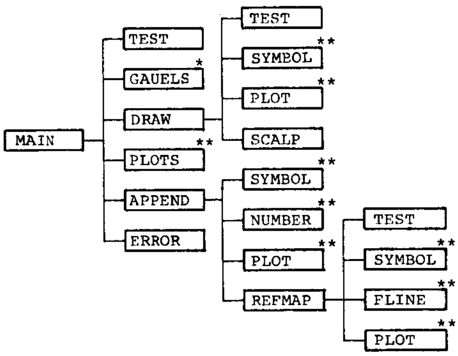
Hugoton embayment area, Texas, Oklahoma, and Kansas: *Am. Assoc. Petroleum Geologists Bull.*, **52**(9), pp. 1655–1661.
YAMAMOTO, K. (1973), The trend surface analysis by computer and its application: *Jour. Geol. Soc. Japan.*, **79**(5), pp. 349–362. (in Japanese with English abstract)
Yoshizawa Business Machine (1969a), *CALCOMP Programming Manual I.* (in Japanese)
Yoshizawa Business Machine (1969b), *ibid II.* (in Japanese)

Appendix; Computer Program

This program is constructed in a simple structure, not overlayed. In this program, FACOM 230–60/75 SSL (Scientific Subroutine Library) and CALCOMP routines (basic and functional ones) are used. They are marked "*" and "**" respectively in the explanations below.

a. Call tree

Main- and sub-programs are connected with each other as shown in Appendix-fig. 1.



Appendix-fig. 1. Call tree. The routine marked "*" and "**" are FACOM 230–60/75 SSL (Scientific Suborutine Library) routine and CALCOMP ones respectively.

b. Function of main- and sub-programs

(1) **Main program**: reads control, source and blank unit specification data, computes grid values, and automatically defines triangular elements as well as the control of the processing flow.

(2) **DRAW**: draws contour lines in each element.

(3) **APPEND**: normally terminates the job, after plotting data points, if required.

(4) **REFMAP**: reads referring map input data and draw a referring map.

(5) **TEST**: checks the repetition times of the main repeating operations.

(6) **ERROR**: detects errors.

(7) **SCALP**: scales plotting data.

(8) **GAUELS***: solves a linear system by Gaussian elemination method (SSL).
(9) **PLOTS****: opens a file in which plotting data are to be stored (CALCOMP routine).
(10) **PLOT****: linearly removes a plot-pen, and in the case of CALL PLOT (0.0, 0.0, 999) close the file (CALCOMP routine).
(11) **SYMBOL****: plots symbol(s) (CALCOMP routine)
(12) **NUMBER****: plots a number (CALCOMP routine)
(13) **FLINE****: draws a smooth line through specified points (CALCOMP routine).

c. Common blocks

Relations among common blocks and main- and sub-programs are shown in Appendix tab. 1.

Appendix-tab. 1. Common blocks.

MAIN & SUBROUTINE	COMMON BLOCKS
MAIN	PNI (for peak # and value)
	OPT1 (for face definition)
	OPT2 (for blank unit definition)
	PRB (for problem/data name)
DRAW	PNI, OPT1, OPT2, PRB,
	AREA (for mapping area specification)
REFMAP	AREA, PRINT (dummy)
APPEND	not used
TEST	not used
ERROR	not used
SCALP	not used

d. Program source list

```
C ***** CONTOUR MAP PROCESSING PROGRAM,NAME...CMPP *****
C
      COMMON          /PNI/     X(1000),Y(1000),Z(1000),NPEK(1000)
     1                /OPT1/    NFDF(3,2000)
     2                /OPT2/    NVIS(2000)
     3                /PRB/     NAME(20)
      DIMENSION       NFOM(20),XI(1000),YI(1000),ZI(1000),AA(3,4),WWW(3),
     1                NCN(16),NO(16), BOUND(4), NSTOR(200),
     2                IFMP(20),IFMF(20)
      DATA            NVIS      /2000*'YES '/,
     1                IFMP      /'(2(I','5,3F','10.,','5X))',16*'    '/,
     2                IFMF      /'(4(3','I5,5','X))',17*'    '/
C
C ***** INPUT, CONTROL DATA *****
      READ (5,1001) NAME
 1001 FORMAT (20A4)
      READ (5,1002) KDATA,IND,IDF,NOPT3,NOPT4,NOPT5,
     1               KSKIP,LDEGIT,BASE,CINT,SCALE1,KNREF,IFSP
 1002 FORMAT (A4,1X,2I5,3(A4,1X),2I5,3F10.0,I5,A4)
      IF(NOPT3 .NE. 'YES ') NOPT3='NO'
      IF(NOPT4 .NE. 'YES ') NOPT4='NO'
      IF(NOPT5 .NE. 'YES ') NOPT5='NO'
      IF(IFSP .NE. 'YES')   IFSP='NO'
      IF (IDF .EQ. 0) IDF = 5
      IF (IND .EQ. 0) IND = 5
      WRITE (6,2001) NAME,KDATA,IFSP,IND,IDF,NOPT3,NOPT4,
     1                NOPT5,KSKIP,LDEGIT,SCALE1,BASE,CINT,KNREF
 2001 FORMAT (1H1///1H ,10X,'CONTOUR MAP PROCESSING'///
     1               1H ,15X,'PROBLEM NAME      ... ',20A4//
     1               1H ,15X,'DATA KIND         ... ',A4/
     1               1H ,15X,'I-FORMAT SPECIF.  ... ',A4/
     1               1H ,15X,'INPUT DEVICE #    ... ',2I5,
     1                                    ' (FOR PEAK & FACE)'/
     2               1H ,15X,'OPTION-3,4,5 ... ',3A5,
     2                  ' (REFERING MAP, BLANK UNITS DEFINITION, '
     2                  'PEAK POINTS PLOTTING)'/
     2               1H ,15X,'SKIP,DEGIT        ... ',2I5/
     3               1H ,15X,'SCALING FACTOR    ... ',F12.4/
     3               1H ,15X,'CONTOUR BASE      ... ',F12.4/
     4               1H ,15X,'CONTOUR INTERVAL  ... ',F12.4/
     5               1H ,15X,'KIND OF REFMAP    ... ',I5//)
      IF (IFSP .NE. 'YES') GO TO 40
      READ (5,1001) IFMP,IFMF
   40 IF (KDATA .NE. 'REGS') GO TO 80
C ***** INPUT, 'REGS' REGULARLY SPACED DATA *****
      IF (IND .NE. 5) REWIND IND
      IF (IND .EQ. 5) GO TO 42
      READ (5,1003) KIND,ID
 1003 FORMAT (A4,1X,I5)
      READ (IND,1004) IDHENT,NOMAP
 1004 FORMAT (A4,I5)
      CALL TEST (1,NOMAP,10,'MAP#')
```

```
      GO TO 43
   42 READ (IND,1013) PX,PY,MAXX,MAXY
 1013 FORMAT (2F10.0,2I5)
      NOMAP = 1
   43 DO 60 I=1,NOMAP
          IF (IND .EQ. 5) GO TO 44
          READ (IND,1005) K1,ID1,PX,PY,MAXX,MAXY
 1005     FORMAT (A4,I5,2F10.0,2I5)
   44     NTEM = MAXX*MAXY
          IF (IFSP .NE. 'YES') GO TO 45
          READ(IND,IFMP) (Z(J),J=1,NTEM)
          GO TO 48
   45     READ (IND,1006) (Z(J) ,J=1,NTEM)
 1006     FORMAT (8(6X,E10.4))
   48     IF (IND .EQ. 5) GO TO 49
          IF (K1 .NE. KIND .OR.ID .NE. ID1) GO TO 60
   49     DO 50 J=1,NTEM
              X(J) =  PX*FLOAT(J-MAXX*((J-1)/MAXX)-1)
              Y(J) =  PY*FLOAT((J-1)/MAXX)
   50     CONTINUE
          WRITE (6,2002) (X(J),Y(J),Z(J),J=1,NTEM)
          GO TO 70
 2002     FORMAT (1H ,3(5X,3F12.4,2H ,))
   60 CONTINUE
      REWIND IND
      STOP 'DATA SET WAS NOT FOUND IN THE FILE'
   70 IF (IND .NE. 5) REWIND IND
      GO TO 200
C ***** INPUT & PROCESSING OF FACE DEFINITION DATA *****
   80 IF (KDATA .NE. 'FDEF') GO TO 100
      READ (5,1007) NOP,NOF,BOUND
 1007 FORMAT (2I5,4F10.0)
      IF (IND .NE. 5) REWIND IND
      IF (IDF .NE. 5) REWIND IDF
      READ (IND,IFMP) (NPEK(I),X(I),Y(I),Z(I),I=1,NOP)
 1008 FORMAT (2(I5,3F10.0,5X))
      READ (IDF,IFMF)((NFDF(I,J),I=1,3),J=1,NOF)
 1009 FORMAT (4(3I5,5X))
      WRITE (6,2003) (NPEK(I),X(I),Y(I),Z(I),I=1,NOP)
 2003 FORMAT(1H ,2(5X,I5,3F12.4,1H,))
      WRITE (6,2004) ((NFDF(I,J),I=1,3),J=1,NOF)
 2004 FORMAT (1H ,4(5X,3I5,1H,))
      CALL PLOTS
      CALL DRAW(NOF,BASE,CINT,SCALE1,NOP)
      CALL APPEND(NOP,NOPT1,NOPT2,NOPT3,NOPT4,NOPT5,KSKIP,LDEGIT,NPEK,
     4                X,Y,Z,KNREF,SCALE1)
C ***** INPUT, PEAK DATA WITHOUT FACE DEFINITION *****
  100 CONTINUE
      IF (KDATA .NE. 'SMTH') STOP 'ILLEGAL DATA KIND'
      READ (5,1010)  NOP,NUNIT, BOUND,PX,PY
 1010 FORMAT (2I5,6F10.0)
      IF (IND .NE. 5) REWIND IND
      READ (IND,IFMP)(NPEK(I),XI(I),YI(I),ZI(I),I=1,NOP)
      IF (IND .NE. 5) REWIND IND
```

```
      WRITE (6,2005) NOP,NUNIT,BOUND,PX,PY,(XI(I),YI(I),ZI(I),I=1,NOP)
 2005 FORMAT (///1H ,10X,'INPUT FOR OPTION-1'//
     1             1H ,10X,'# OF OBSERVATIONS ...',I5/
     1             1H ,10X,'NUNIT             ...',I5/
     2             1H ,10X,'BOUNDARY,1,2,3,4 ...',4F12.4/
     3             1H ,10X,'X-PITCH, Y-PITCH   ...',2F12.4//
     4             1H ,5X,'X,Y,Z'/
     5             1H ,2(5X,3F12.4,2H /))
C ***** ESTIMATION OF GRID VALUES *****
      MAXX =(BOUND(2)-BOUND(1))/PX + 1.0
      MAXY =(BOUND(4)-BOUND(3))/PY + 1.0
      III = 0
      CALL TEST (4,NOP,1000,'NOP')
      CALL TEST (2,MAXX,200,'MAXX')
      CALL TEST (3,MAXY,200,'MAXY')
      DO 180 J= 1,MAXY
          YTEMP= BOUND(3) + PY*FLOAT(J-1)
          DO 170 I=1,MAXX
              III = III + 1
              NNN = IABS(NUNIT)
              XTEMP = BOUND(1) + PX*FLOAT(I-1)
  105         X1 = XTEMP - PX*FLOAT(NNN)
              X2 = XTEMP + PX*FLOAT(NNN)
              Y1 = YTEMP - PY*FLOAT(NNN)
              Y2 = YTEMP + PY*FLOAT(NNN)
              DO 110 M=1,3
                  DO 110 N=1,4
                      AA(M,N) = 0.0
  110         CONTINUE
              NSTOR(I) = NNN
              NPPP = 0
              DO 140 L=1,NOP
                  IF (XI(L) .LT. X1 .OR. XI(L) .GT. X2) GO TO 140
                  IF (YI(L) .LT. Y1 .OR. YI(L) .GT. Y2) GO TO 140
                  NPPP = NPPP + 1
                  WWW(1) = 1.0
                  WWW(2) = XI(L)
                  WWW(3) = YI(L)
                  DO 130 M=1,3
                      DO 120 N=M,3
                          AA(M,N) = AA(M,N) + WWW(M)*WWW(N)
                          AA(N,M) = AA(M,N)
  120                 CONTINUE
                      AA(M,4) = AA(M,4) + WWW(M)*ZI(L)
  130             CONTINUE
  140          CONTINUE
               IF (NPPP .LT. 5) GO TO 150
               CALL GAUELS(AA,3,3,4,1.0E-10,ILL)
               IF (ILL .NE. 0) CALL ERROR(1)
               X(III) = XTEMP
               Y(III) = YTEMP
               Z(III) = AA(1,4) + XTEMP*AA(2,4) + YTEMP*AA(3,4)
               GO TO 170
  150          IF (NUNIT .LE. 0) GO TO 160
```

```
                NNN = NNN + 1
                GO TO 105
 160            X(III) = XTEMP
                Y(III) = YTEMP
              . Z(III) = 1.0E20
 170        CONTINUE
            LS = MAXX*(J-1) + 1
            LE = LS + MAXX - 1
            WRITE(6,9001) J,(NSTOR(I),I=1,MAXX)
9001        FORMAT(1H ,10X,'SMOOTHED'/1H ,5X,'# OF UNITS & X,Y,Z'/
   1             1H ,I5,'.... ',25I5/(1H ,10X,25I5))
            WRITE (6,9002) (X(K),Y(K),Z(K),K=LS,LE)
9002        FORMAT(1H ,5X,10E13.6)
 180 CONTINUE
 200 CONTINUE
     CALL TEST (2,MAXX,200,'MAXX')
     CALL TEST (3,MAXY,200,'MAXY')
     IF (NOPT4 .NE. 'YES ') GO TO 250
C ***** BLANK UNITS SPECIFICATION *****
 205 READ (5,1012) (NO(I),NCN(I),I=1,16)
     I = 1
 210 CONTINUE
1012 FORMAT (16(I4,A1))
            IF (NCN(I) .EQ. '-') GO TO 220
            J = 2*NO(I)
            NVIS(J) =.'NO  '
            NVIS(J-1)='NO  '
            IF (NCN(I) .EQ. '/') GO TO 250
            I = I + 1
            GO TO 240
 220        IF (I .EQ. 16) CALL ERROR(2)
            DO 230 J=NO(I),NO(I+1)
                NVIS(2*J)   = 'NO  '
                NVIS(2*J-1) = 'NO  '
 230        CONTINUE
            IF (NCN(I+1) .EQ. '/') GO TO 250
                I = I + 2
 240        IF (I .GT. 16)       GO TO 205
            IF (NO(I)    .EQ. 0) GO TO 205
            GO TO 210
 250 CONTINUE
            NOPC = MAXX*MAXY
            DO 255 I=1,NOPC
                NPEK(I) = I
 255 CONTINUE
C ***** TRIANGLE ELEMENTS DEFINITION *****
     NNN = (MAXX-1)*(MAXY-1)
     DO 260 J=1,NNN
            JTEM = J + (J-1)/(MAXX-1)
            JJJ  = 2*J - 1
            NFDF(1,JJJ) = JTEM
            NFDF(2,JJJ) = JTEM + 1
            NFDF(3,JJJ) = JTEM + MAXX
            IF (Z(JTEM)        .EQ. 1.0E20) NVIS(JJJ) = 'NO  '

            IF (Z(JTEM+1)     .EQ. 1.0E20) NVIS(JJJ) = 'NO  '
            IF (Z(JTEM+MAXX) .EQ. 1.0E20) NVIS(JJJ) = 'NO  '
            JJJ = 2*J
            NFDF(1,JJJ) = JTEM + 1
            NFDF(2,JJJ) = JTEM + MAXX + 1
            NFDF(3,JJJ) = JTEM + MAXX
            IF (Z(JTEM+MAXX+1) .EQ. 1.0E20) NVIS(JJJ) = 'NO  '
            IF (Z(JTEM+MAXX)   .EQ. 1.0E20) NVIS(JJJ) = 'NO  '
            IF (Z(JTEM+1)      .EQ. 1.0E20) NVIS(JJJ) = 'NO  '
 260 CONTINUE
     CALL PLOTS
     NOF = 2*NNN
     CALL DRAW(NOF,BASE,CINT,SCALE1,NOPC)
     DO 280 I=1,NOP
         XI(I) = (XI(I) - BOUND(1))/SCALE1
         YI(I) = (YI(I) - BOUND(3))/SCALE1
 280 CONTINUE
     CALL APPEND(NOP,NOPT1,NOPT2,NOPT3,NOPT4,NOPT5,KSKIP,LDEGIT,NPEK,
   1              XI,YI,ZI,KNREF,SCALE1)
     END
```

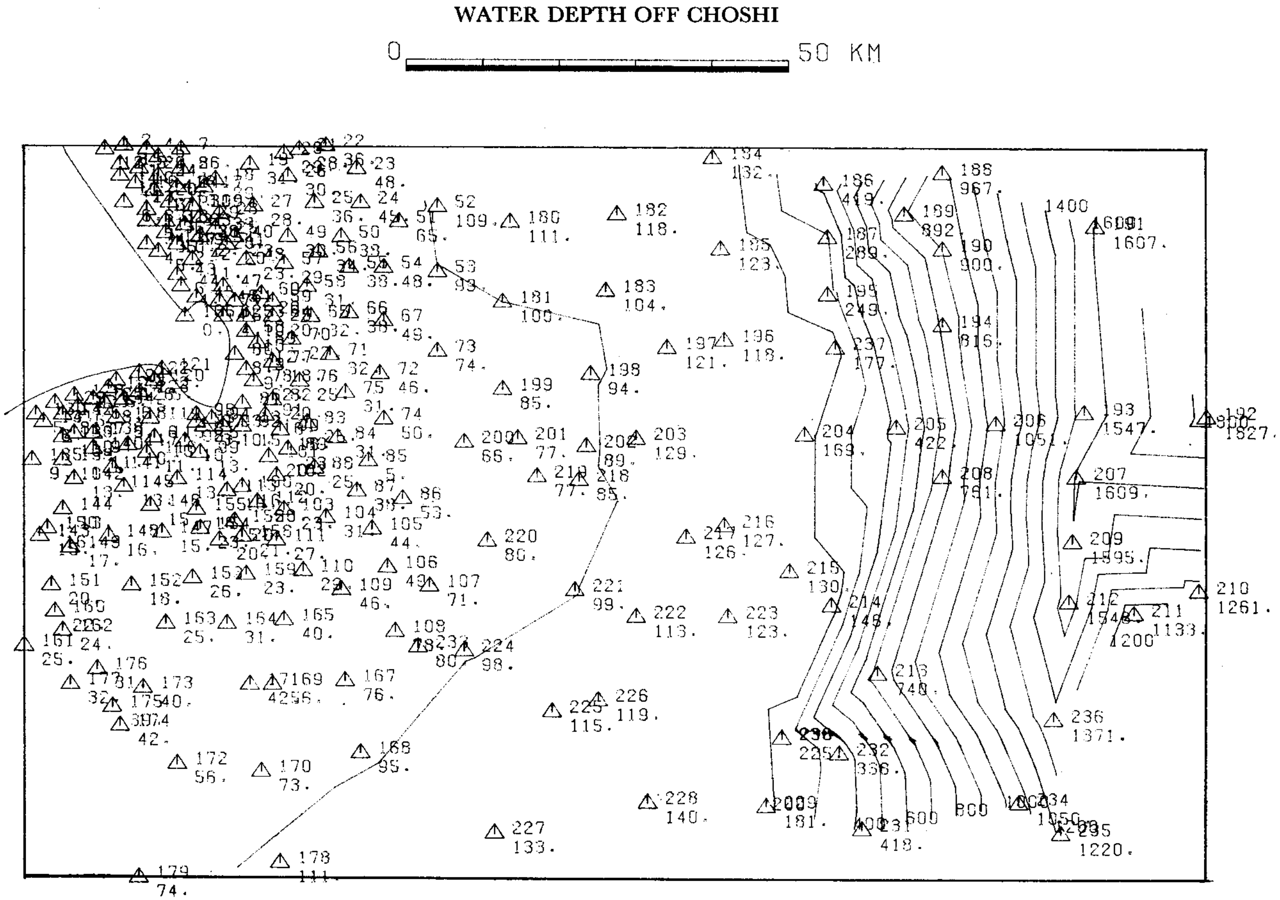
```
C ***** CONTOUR DRAW, NAME...DRAW *****
C
      SUBROUTINE DRAW(NOF,BASE,CINT,SCALE1,NOP)
      COMMON            /PRB/      NAME(20)
     1                  /PNI/      X(1000),Y(1000),Z(1000),NPEK(1000)
     2                  /OPT1/     NFDF(3,2000)
     3                  /OPT2/     NVIS(2000)
     3                  /AREA/     BOUND(4)
      DIMENSION         ZM(3), MO(3), XT(10), YT(10)
C
      K = 1
C ***** MAP LABEL PLOTTING *****
      CALL SYMBOL       ( 3.0,10.0,1.5,NAME,90.0,40)
      CALL PLOT(10.0, 5.0,-3)
      WRITE (6,2001)
 2001 FORMAT (1H1///1H ,10X,'CONTOUR DRAW START'/)
      CALL TEST (4,NOP,1000,'NOP')
      CALL TEST  (5,NOF,2000,'NOF')
C ***** SCALING OF DATA (X,Y,Z) *****
      CALL SCALP(X,65.0,NOP,1)
      CALL SCALP(Y,90.0,NOP,1)
      CALL SCALP(Z,100.0,NOP,1)
      IF (SCALE1 .NE. 0.0) GO TO 20
      SCALE1 = X(NOP+2)
      IF (Y(NOP+2) .GT. SCALE1) SCALE1 = Y(NOP+2)
   20 DO 30 I=1,NOP
         X(I) = (X(I)-X(NOP+1))/SCALE1
         Y(I) = (Y(I)-Y(NOP+1))/SCALE1
   30 CONTINUE
      BOUND(1) = X(NOP+1)
      BOUND(3) = Y(NOP+1)
C ***** CONTOURING START *****
      DO 250 I=1,NOF
         IF (NVIS(I) .EQ. 'NO') GO TO 250
         DO 42 N=1,3
         DO 40 J=1,NOP
            IF (NPEK(J) .EQ. NFDF(N,I)) GO TO 41
   40    CONTINUE
   41    MO(N) = J
         ZM(N) = Z(J)
   42    CONTINUE
         BIG = ZM(1)
         DO 50 J=2,3
            IF (ZM(J) .LE. BIG) GO TO 50
               ZM(1) = ZM(J)
               ZM(J) = BIG
               BIG = ZM(1)
               MTEM= MO(1)
               MO(1) = MO(J)
               MO(J) = MTEM
   50    CONTINUE
         IF (ZM(2) .GE. ZM(3)) GO TO 60
```

```
      BIG =ZM(3)
      ZM(3) = ZM(2)
      ZM(2) = BIG
      MTEM  = MO(3)
      MO(3) = MO(2)
      MO(2) = MTEM
   60 CON = BASE + CINT*(FLOAT(INT((ZM(3)-BASE)/CINT))+1.0)
      MAXL = 100
      DO 210 J=1,MAXL
          IL = J - 1
          IF(CON .GT. ZM(1)) GO TO 220
          LRR = 1
          MMM = 0
          ZZ1 =ZM(3)
          M1  = MO(3)
          ZZ2 = ZM(2)
          M2  = MO(2)
   70     IF (CON .GT.ZZ1.AND. CON .LE. ZZ2) GO TO 80
          GO TO 90
   80     CONTINUE
          MMM = MMM + 1
          XT(MMM) = X(M1)+(X(M2)-X(M1))*(CON-ZZ1)/(ZZ2-ZZ1)
          YT(MMM) = Y(M1)+(Y(M2)-Y(M1))*(CON-ZZ1)/(ZZ2-ZZ1)
   90     IF (MMM .EQ. 2) GO TO 110
          IF (LRR .EQ.3) GO TO 200
          IF (MMM .EQ.1) GO TO 100
              ZZ1 = ZM(2)
              ZZ2 = ZM(1)
              M1  = MO(2)
              M2  = MO(1)
              LRR = LRR + 1
              GO TO 70
  100     ZZ1 = ZM(3)
          ZZ2 = ZM(1)
          M1  = MO(3)
          M2  = MO(1)
          LRR = LRR + 1
          GO TO 70
C     ***** PLOT A LINE *****
  110     CONTINUE
          CALL PLOT(YT(1),XT(1),3)
          CALL PLOT(YT(2),XT(2),2)
  200 CON = CON + CINT
  210 CONTINUE
      WRITE(6,2004) MAXL
  220 WRITE (6,2002) I,(NFDF(K,I),K=1,3),ZM,MO,IL
  250 CONTINUE
 2002 FORMAT (1H ,5X,I5,1X,'(',3I5,')',3F12.3,2X,3I5,3X,'# OF LINES',
     1            '...',I3)
      WRITE (6,2003)
 2003 FORMAT (1H ,10X,'ALL CONTOUR LINES DRAWN')
 2004 FORMAT (/1H ,10X,'LINES TO BE DRAWN OVER',I5/)
      RETURN
      END
```

```
C ***** PLOT REFERENCE POINTS/LINES, NAME...REFMAP ***
C
      SUBROUTINE REFMAP(KIND,SCALE)
C
      COMMON          /PRINT/   MOUT
     1                /AREA/    BOUND(4)
      DIMENSION       XP(100), YP(100), NAMEPO(100,5), SIZEP(100,2),
     1                NFOM(100),
     2                NPFOLN(10),XL(10,100),YL(10,100),
     3                NAMELN(10,5), SIZEL(10,2),
     4                NAMTEM(5), XX(102), YY(102), NVALUE(2)
C
      IF (KIND .EQ. 0) GO TO 250
      KKK = IABS(KIND)
      GO TO (10,50,10),KKK
C ***** INPUT, REFERING POINT(S) DATA *****
   10 READ (5,1001) NUMBER
 1001 FORMAT (I5)
      CALL TEST (11,NUMBER,100,'RPO#')
      DO 30 I=1,NUMBER
          READ (5,1002) XP(I),YP(I),SIZEP(I,1),SIZEP(I,2),
     1                  (NAMEPO(I,J),J=1,5),NFOM(I)
 1002     FORMAT (4F10.0,5A4,I5)
   30 CONTINUE
          WRITE (6,2001) NUMBER,(XP(I),YP(I),SIZEP(I,1),SIZEP(I,2),
     1                   (NAMEPO(I,J),J=1,5),NFOM(I),I=1,NUMBER)
 2001     FORMAT (///1H ,10X,'INPUT (REFERENCE POINTS),',I5,' POINTS'//
     1             (1H ,15X,4F12.3,5X,5A4,I5))
   40 CONTINUE
      IF (KKK .EQ. 1) GO TO 90
C ***** INPUT, REFERING LINE(S) DATA *****
   50 READ (5,1003) NLINE
 1003 FORMAT (I5)
      CALL TEST (12,NLINE,10,'RLN#')
      DO 70 I=1,NLINE
          READ (5,1004) NPFOLN(I),SIZEL(I,1),SIZEL(I,2),
     1                  (NAMELN(I,J),J=1,5)
 1004     FORMAT (I5,2F10.0,5A4)
          CALL TEST (13,NPFOLN(I),100,'RLP#')
          READ (5,1005) (XL(I,J),YL(I,J),J=1,NPFOLN(I))
 1005     FORMAT (8F10.0)
   70 CONTINUE
          WRITE(6,2002) NLINE
 2002     FORMAT (///1H ,10X,'INPUT (REFERENCE LINES),',I5,' LINES'/)
          DO 80 I=1,NLINE
              WRITE (6,2003) NPFOLN(I),SIZEL(I,1),SIZEL(I,2),
     1                       (NAMELN(I,J),J=1,5),
     2                       (XL(I,J),YL(I,J),J=1,NPFOLN(I))
 2003         FORMAT (1H ,15X,I5,2F12.3,5X,5A4/(1H ,5X,8F12.3))
   80     CONTINUE
   90 CONTINUE
      GO TO (100,200,100),KKK
```

```
C ***** PLOT, REFERING POINT(S) *****
  100 DO 120 I=1,NUMBER
      DO 110 J=1,5
          NAMTEM(J) = NAMEPO(I,J)
  110 CONTINUE
      YTEM = (XP(I)-BOUND(1))/SCALE
      XTEM = (YP(I)-BOUND(3))/SCALE
      CALL SYMBOL(XTEM,YTEM,SIZEP(I,1),NFOM(I),90.0,-1)
      XTEM = XTEM + SIZEP(I,1) + SIZEP(I,2)
      CALL SYMBOL(XTEM,YTEM,SIZEP(I,2),NAMTEM,90.0,20)
  120 CONTINUE
      WRITE(6,2005)
      IF (KKK .EQ. 1) GO TO 250
  200 CONTINUE
C ***** PLOT, REFERING LINE(S) *****
      DO 240 I=1,NLINE
          DO 210 J=1,5
              NAMTEM(J) = NAMELN(I,J)
  210     CONTINUE
          DO 220 J=1,NPFOLN(I)
              YY(J) = (XL(I,J)-BOUND(1))/SCALE
              XX(J) = (YL(I,J)-BOUND(3))/SCALE
  220     CONTINUE
          XTEM = XX(J) + SIZEL(I,1)
          YTEM = YY(J) + SIZEL(I,1)
          XX(NPFOLN(I)+1) = 0.0
          XX(NPFOLN(I)+2) = 1.0
          YY(NPFOLN(I)+1) = 0.0
          YY(NPFOLN(I)+2) = 1.0
          CALL FLINE(XX,YY,-NPFOLN(I),1,0,64)
          CALL SYMBOL(XTEM,YTEM,SIZEL(I,1),NAMTEM,SIZEL(I,2),20)
  240 CONTINUE
      WRITE(6,2006)
  250 CONTINUE
C ***** INPUT & PLOT, MAP SCALE *****
      IF (KIND .GT. 0) RETURN
      READ (5,1006) DIST,MARK,NVALUE
 1006 FORMAT (F10.0,I5,2A4)
      WRITE (6,2004) DIST,MARK,NVALUE
 2004 FORMAT (1H ,10X,'INPUT (REFERENCE SCALE)'/
     1          1H ,15X,'LENGTH, # OF MARKS,VALUE',5X,F12.3,I5,2A4)
  255 WID = 0.03*DIST
      DL = WID/40.0
      PMA = 10.0
      PIC = DIST/FLOAT(MARK-1)
      XTEM = -2.0 - WID
      CALL TEST (14,MARK,200,'MARK')
      DO 260 I=1,MARK
          CALL PLOT(-2.0,PMA,3)
          CALL PLOT(XTEM,PMA,2)
          PMA = PMA + PIC
  260 CONTINUE
      XTEM = -2.0
      YTEM = 10.0 + DIST

      DO 270 K=1,20
          CALL PLOT(XTEM,10.0,3)
          CALL PLOT(XTEM,YTEM,2)
          XTEM = XTEM - DL
  270 CONTINUE
      XTEM = -2.0 - WID
      CALL PLOT(XTEM,10.0,3)
      CALL PLOT (XTEM,YTEM,2)
      YTEM = YTEM + WID
      HHH = 1.5*WID
      CALL SYMBOL(XTEM,YTEM,HHH,NVALUE,90.0,8)
      WRITE(6,2007)
      RETURN
 2005 FORMAT (/1H ,10X,'REFERING POINTS PLOTTED'/)
 2006 FORMAT (/1H ,10X,'REFERING LINES  PLOTTED'/)
 2007 FORMAT (/1H ,10X,'MAP SCALE PLOTTED'/)
      END
```

```
C ***** DATA POINTS PLOTTING AND JOB TERMINATING ROUTINE, NAME... APPEND
      SUBROUTINE APPEND(NOP,N1,N2,N3,N4,N5,K,L,NPEK,X,Y,Z,KNREF,SCALE1)
C
      DIMENSION       X(NOP),Y(NOP),Z(NOP),NPEK(NOP)
      IF (N5.NE. 'YES ') GO TO 100
      IF (K .EQ. 0) K='
      DO 50 I=1,NOP,K
          CALL SYMBOL(Y(I),X(I),0.5,2,90.0,-1)
          YTEM = Y(I)
          XTEM = X(I) + 0.5
          TEMP = NPEK(I)
          CALL NUMBER(YTEM,XTEM,0.3,TEMP,90.0,-1)
          IF (L .LT. 0) GO TO 50
          YTEM = YTEM + 0.5
          CALL  NUMBER(YTEM,XTEM,0.3,Z(I),90.0,L)
   50 CONTINUE
      WRITE(6,2001)
 2001 FORMAT(1H ,10X,'DATA POINTS PLOTTED')
C ***** REFERNG MAP PLOTTING *****
  100 IF (N3 .EQ. 'YES ') CALL REFMAP(KNREF,SCALE1)
C ***** NORMALLY TERMINATE THE JOB *****
      CALL PLOT(0.0,0.0,999)
      STOP 'NORMAL END OF JOB'
      END

C ***** AMOUNT TEST ROUTINE, NAME ... TEST *****
      SUBROUTINE TEST (ITEM,NV,LIMIT,NAME)
      IF (NV .GT. 0 .AND. NV .LE. LIMIT) RETURN
      WRITE (6,1001) ITEM,NAME,NV,LIMIT
 1001 FORMAT (1H ,'**ERROR**  CONTROL VALUE IS ILLEGAL ... ',
     1             'ITEM#',I5,'(',A4,')  VALUE =',I12,'(LIMIT',I6,')'/)
      STOP
      END

C ***** ERROR ROUTINE, NAME ... ERROR *****
      SUBROUTINE ERROR(I)
C
      CALL PLOT (0.0,0.0,999)
      GO TO (10,20) ,I
   10 STOP 'GAUELS ERROR, APPROXIMATING PLANE WAS NOT DETARMINED'
   20 STOP 'BLANK AREAS DEFINITION ERROR (-)'
      END

      SUBROUTINE SCALP(A,W,N,M)
      DIMENSION A(N)
      BIG = A(1)
      SMAL = A(1)
      DO 20 I=1,N,M
          IF (A(I) .GT.  BIG) BIG  = A(I)
          IF (A(I) .LT. SMAL) SMAL = A(I)
   20 CONTINUE
      A(N+M) = SMAL
      A(N+2*M) = (BIG-SMAL)/W
      RETURN
      END
```



Supplement figure. Output example of the revised program: map is framed and contour values are written at ends of every two lines.

Supplement

The program was revised. The revised one can frame the output map and write their values along the contours as shown in the supplement figure in which the values are written every two contours. (Supplement figure)